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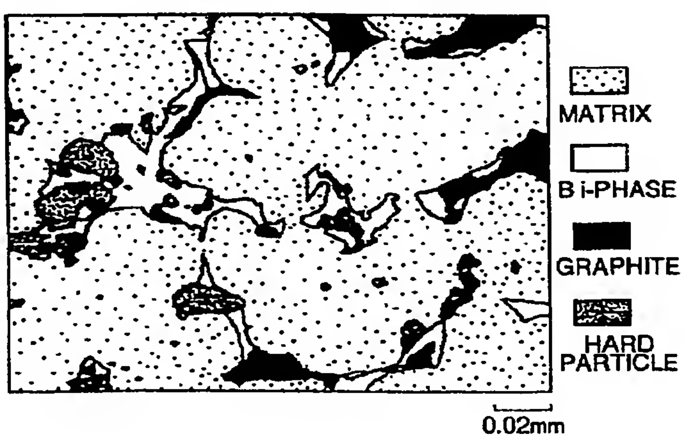
C7A AB249 AB25Y AB250 AB26X AB261 AB263 AB265 AB267 AB269 AB27X AB271 AB273 AB275 AB277 AB279 AB289 AB309 AB319 AB32X AB32Y AB320 AB349 AB369 AB37Y AB370 AB375 AB377 AB379 AB38X AB381 AB383 AB385 AB387 AB389 AB399 AB419 AB42Y AB420 AB422 AB424 AB425 AB427 AB429 AB43X AB431 AB433 AB435 AB437 AB439 AB44Y AB440 AB449 AB45X AB451 AB453 AB455 AB46Y AB460 AB469 AB470 AB473 AB475 AB477 AB479 AB48X AB481 AB483 AB485 AB487 AB489 AB50Y AB500 AB509 AB51X AB511 AB513 AB515 AB517 AB519 AB52X AB52Y AB528 AB53X AB531 AB533 AB535 AB537 AB539 AB54X AB54Y AB543 AB545 AB546 AB547 AB548 AB549 AB55X AB55Y AB553 AB555 AB556 AB557 AB558 AB559 AB610 AB613 AB616 AB617 AB62X AB62Y AB620 AB621 AB624 AB627 AB630 AB635 AB66X AB66Y AB661 AB662 AB663 AB664 AB665 AB666 AB667 AB668 AB669 AB670 AB672 AB675 AB682 AB683 AB684 AB685 AB686 AB687 AB688 AB70X AB702 A71X A71Y A713 A747 A748 A749 A757 A782 A783

(56) and (58) continued overleaf

(54) Abstract Title
Copper sliding bearing alloy

(57) A copper alloy comprises 0.5-15 mass % tin, 1-20 mass % bismuth and 0.1-10 volume % hard particles having an average size of 1-45 µm. The bismuth exists as a bismuth phase dispersed through the alloy. The hard particles may comprise one or more of borides, silicides, oxides, nitrides, carbides and/or an intermetallic. The alloy may further comprise not more than 40 mass % of Fe, Al, Zn, Mn, Co, Ni, Si and/or P. It may also further comprise not more than 20 volume % of one or more of MoS_2, WS_2, BN and graphite. The alloy may be formed using powder metallurgy and may used in bushes or thrust washers.

FIG.1A



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(56) Documents Cited

GB 2312679 A	EP 0681035 A2	WO 99/20806 A1
JP 080283889 A	JP 080053725 A	JP 070310133 A
JP 070150273 A	JP 020194134 A	US 5938864 A

(58) Field of Search
INT CL^7 C22C
Online: PAJ, WPI

FIG.1A

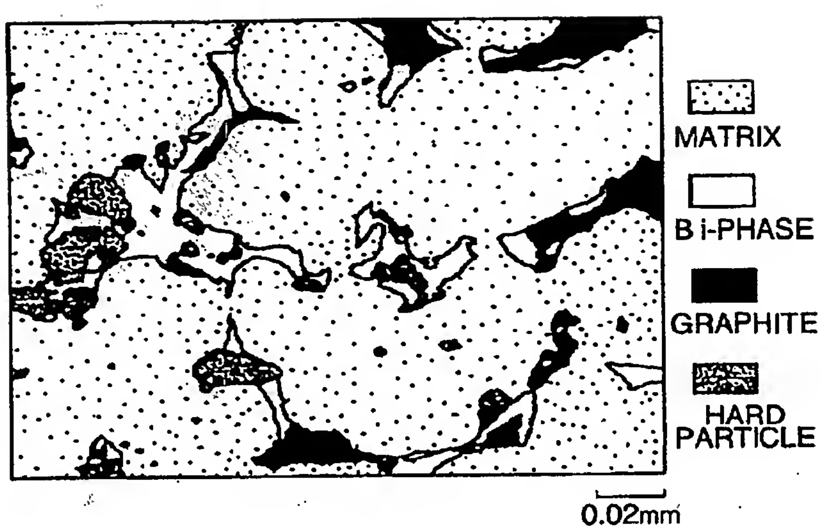
MATRIX
B i-PHASE
GRAPHITE
HARD PARTICLE
0.02mm

FIG.1B

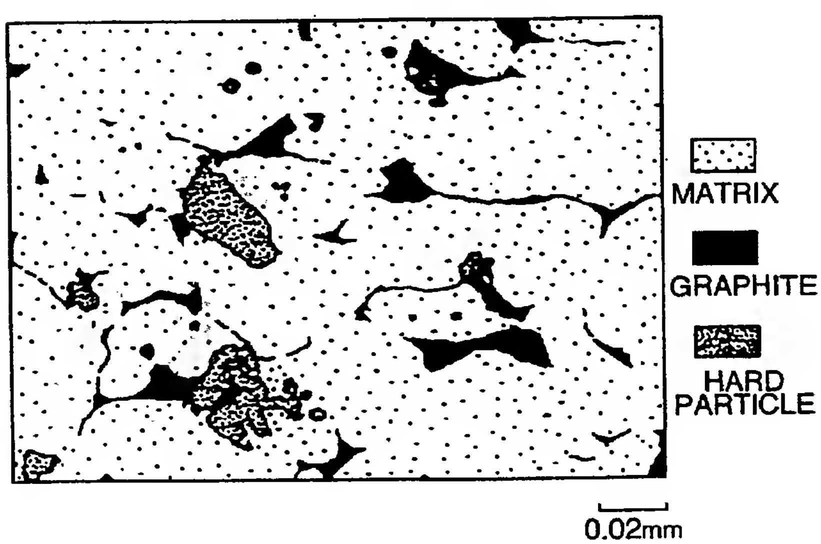
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FIG.2

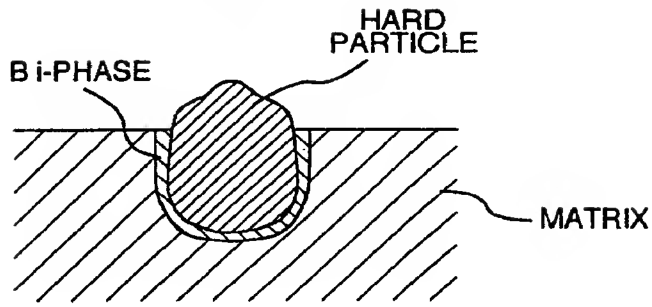


FIG.3

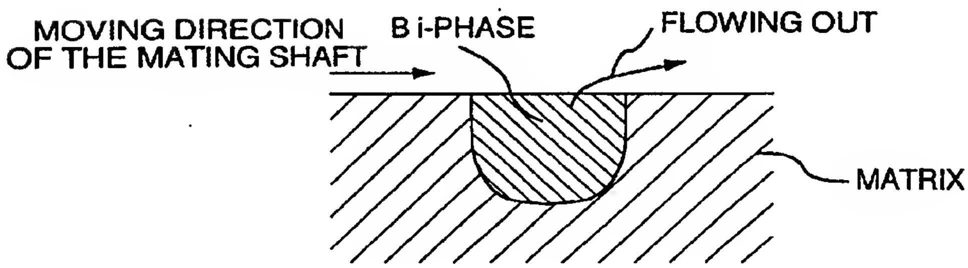
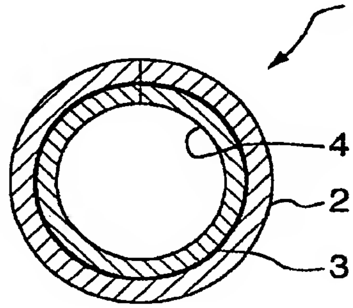


FIG.4



SLIDING MATERIAL OF COPPER ALLOY

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to a copper system sliding material having excellent wear resistant property and excellent anti-seizure property, particularly the copper system sliding material suitable for bushes or thrust washers which are used in motor vehicles, industrial machines, agricultural machines and so on.

2. Brief description of the art

Conventionally, there have been used primarily sintered alloys such as bronze or lead-bronze. These alloys exhibit good sliding-contact property under a lubricant existing condition. But, the copper system alloys have not satisfactory sliding-contact property, especially because they are inferior in wear resistance, under the condition of boundary lubrication region wherein an oil film is not enough formed when a low viscosity lubricant is used or an enough amount of lubricant is not supplied.

In order to improve the wear resistance property of known sliding materials under the condition of boundary lubrication, the assignee proposed a sintered alloy (see JP-A-4-198440). The sintered alloy consists of 1 to 15 mass% Sn, 1 to 20

mass% of Ni-B, not more than 1 mass% P, and balance of Cu and inevitable impurities, in which the hard Ni-B is dispersed in the copper alloy so that the wear resistance property is improved. But, the sintered alloy has not satisfactory sliding-contact property under the state that an edge loaded sliding-contact or abrasive wear is liable to occur.

In order to improve the defect, the assignee proposed a copper system sliding material (JP Pat. Appln. No. 10 -112799 which was filed on April 7, 1998 and published on October 26, 1999) of a Cu-Sn-Pb alloy in which 2 to 30 mass% Pb is dispersed, wherein the Pb phase contains 0.1 to 6 vol% of hard particles each having an average grain size of 5 to 25 μm. The copper system sliding material exhibits good wear resistance property and anti-seizure property because Pb is dispersed in the copper alloy matrix to form the Pb phase which entrains the hard particles. But, Pb is used in the improved copper system sliding material. It is preferable to decrease or even avoid to use additive Pb in the copper system sliding material because lead adversely affects on the environment.

The present invention has been proposed in view of the above.

An object of the invention is to provide a copper system sliding material according to which the wear resistance and anti-seizure properties can be

improved while decreasing additive lead or even avoiding to use lead.

BRIEF SUMMARY OF THE INVENTION

According to one aspect of the invention, there is provided the copper system sliding material which consists of a copper alloy comprising 0.5 to 15 mass% Sn, 1 to 20 mass% Bi and 0.1 to 10 vol% of hard particles, wherein Bi is present as a Bi-phase and the Bi-phase is dispersed in the copper alloy, and wherein the hard particles, each having a grain size of 1 to 45 µm, coexist together with the Bi-phase.

Bi is dispersed in the copper alloy matrix to form the Bi-phase with which the hard particles coexist. Since the soft Bi-phase is dispersed in the copper alloy matrix, the copper system sliding material is improved in comformability, foreign substances embeddability and anti-seizure property.

The hard particles contribute to improving wear resistance. When the hard particles coexist with the Bi-phase, the copper system sliding material can have excellent wear resistant property and improved anti-seizure property.

According to the hard particles coexisting with the soft Bi-phase, it is possible to restrain those exposed on the surface of the copper alloy matrix not to excessively attack the mating member at

the sliding contact surface because of cushioning property of the soft Bi-phase as shown in Fig. 2.

In the case of the Bi-phase without hard particles, as illustrated in Fig. 3, the Bi-phase is liable to be taken away along the sliding-contact surface during sliding operation resulting in deterioration of wear resistance property. In contrast, according to the copper system sliding material as defined in claim 1, Bi is prevented to flow out from its initial position through coexisting hard particles. Moreover, even if a hard particle is left from one of Bi-phase grains, it is caught again by another Bi-phase grain because of good embeddability of the Bi-phase so that the abrasive wear is restrained.

Bi in an amount of 1 to 20 mass% is dispersed in the copper alloy matrix to form the Bi-phase and improves wear resistance property, anti-seizure property and cushioning property as mentioned above. If the amount of Bi is less than 1 mass%, the anti-seizure effect can not be obtained and the hard particles may attack the mating member because the Bi-phase can not entrain enough the hard particles. If the amount of Bi exceeds 20 mass%, the copper system sliding material is deteriorated in strength.

0.1 to 10 vol% (volume percent) of the hard particles improves the wear resistance property and anti-seizure property of the copper system sliding

material. If the volume percent of the hard particles is less than 0.1 vol%, the wear resistance property is not improved. If the volume percent of the hard particles exceeds 10 vol%, they attack the mating member more intensely.

In the present invention, the hard particles have an average grain size of 1 to 45 μm. If the average grain size is less than 1 μm, the hard particles are hard to uniformly disperse in the Bi-phase and there can not be seen significant improvement of wear resistance property. If the average grain size exceeds 45 μm, in the case where the Bi amount is relatively smaller, there can not be seen the effects of Bi-phase which are properties of cushioning and embeddability for hard particles and the hard particles attack the mating member more intensely.

Sn strengthens the copper matrix of the copper alloy. Less than 0.5 mass% Sn does not strengthen the copper matrix. If Sn exceeds 15 mass%, a lot of Cu-Sn compound is formed to make the copper matrix brittle.

According to one feature of the invention the hard particles may be one or more of boride, silicide, oxcide, nitride, carbide and an intermetallic compound.

According to another feature of the invention, the copper alloy comprises not more than 40 mass% of one or more elements of Fe, Al, Zn, Mn,

Co, Ni, Si and P in an amount or a total amount. Not more than 40 mass% of one or more elements of Fe, Al, Zn, Mn, Co, Ni, Si and P are dissolved in the copper matrix and contribute to strengthening of the copper matrix.

According to still another feature of the invention, the copper alloy comprises not more than 20 vol% of one or more of MoS_2, WS_2, BN and graphite in an amount or a total amount. Respective MoS_2, WS_2, BN and graphite acts as a solid lubricant. These lubricants improve wear resistance property and anti-seizure property of the copper alloy because of those lubrication property. However, if the lubricants exceed 20 vol%, strength of the copper alloy is deteriorated.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A shows schematically a microstructure of a sliding material layer, of the invention, which is a result of electron microscopic observation;

Fig. 1B is a schematic drawing of microstructure of a sliding material layer of a comparative example, which was prepared on the basis of an electron microscopic observation;

Fig. 2 is a cross sectional drawing of an essential part of the invention sliding material, which illustrates a hard particle at the sliding contact surface;

Fig. 3 is a cross sectional drawing of an essential part of a comparative sliding material, which illustrates Bi-phase at the sliding contact surface; and

Fig. 4 is a cross sectional drawing of a plain bearing as one embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

Herein below, a bearing according to the invention is described with reference to the attached drawings.

A bearing 1 is shown in Fig. 4, which is usually called a bush and which comprises a back metal 2 made of a steel sheet and a sliding material layer 4 being formed on the back metal 2 through a bond layer 3 that is provided in order to securely hold the sliding material layer 4 to the back metal 2 and consists of, for example, nickel, copper or a nickel-copper alloy.

The sliding material layer 4 is of a copper system alloy which comprises 0.5 to 15 mass% Sn, 1 to 20 mass% Bi and 0.1 to 10 vol% of hard particles and the balance being essentially Cu and inevitable impurities. The hard particles are of a powder having preferably an average grain size of 1 to 45 μm and may be boride, silicide, oxide, nitride, carbide and an intermetallic compound.

Boride may be NiB, Ni_3B, CrB, ZrB_2, CoB, TiB_2, VB_2, TaB_2, WB, MoB or an Fe-B system.

Silicide may be $TiSi_2$, WSi_2, $MoSi_2$, $TaSi_2$, $CrSi_2$, an Fe-Si system or an Mn-Si system.

Oxide may be SiO_2, Al_2O_3, TiO_2, ZrO_2, WO, MoO_3, an Mn-O system, an Fe-O system or a V-O system.

Nitride may be Si_2N_4, TiN, ZrN, TaN, VN, AlN, C-BN or Cr_2N.

Carbide may be WC, SiC, B_4C, TiC, TaC, VC or ZrC.

An intermetallic compound may be an Ni-Sn system, an Fe-W system, an Fe-Mo system, an Fe-Mn system, an Fe-Cr system, an Fe-Al system, a Cr-Al system, a V-Al system, a Ti-Al system or a W-Al system.

The hard particles may comprise Ni base brazing filler metals (i.e. an Ni-B-Si system alloy) and Co base brazing filler metals (i.e. a Co-Mo-Si-B system alloy).

The copper system alloy of the sliding material layer 4 may further comprises not more than 40 mass% of one or more elements of Fe, Al, Zn, Mn, Co, Ni, Si and P in an amount or a total amount, wherein preferable amounts are not more than 4 mass% Fe, not more than 10 mass% Al, not more than 35 mass% Zn, not more than 10 mass% Mn, not more than 5 mass% Co, not more than 40 mass% Ni, not more than 5 mass% Si and not more than 0.5 mass% P. The copper system alloy may comprises also not more than 20 vol% of a solid

lubricant which consists of one or more of MoS_2, WS_2, BN and graphite.

Here, one embodiment of manufacturing process for the bearing 1 is described.

First, several types of powder, which are 1 to 20 mass% of a Bi powder, 0.1 to 10 vol% of hard particles, 0.5 to 15 mass% of an Sn powder and the balance of a Cu powder, are mixed with one another so that an admixture powder for producing the sliding material layer 4 is obtained. Preferably, the Bi, Sn and Cu powders have a grain size of not more than 250 µm, respectively, and the hard particles have an average grain size of 1 to 45 µm. It is possible to further mix to the above powders with not more than 40 mass% of a powder which has a grain size of not more than than 250 µm and consists of one or more elements of Fe, Al, Zn, Mn, Co, Ni, Si and P, or a solid lubricant powder consisting of one or more of MoS_2, WS_2, BN and graphite. The above powders may be an alloy powder, respectively.

The thus obtained admixture powder for the sliding material layer 4 is uniformly laid or dispersed on a steel plate (i.e. the back metal 2) on which an electroplated copper layer (i.e. the bond layer 3) has been previously provided. The steel plate with the powder is sintered in a reducing atmosphere at 750 to 950°C for 20 minutes, and subsequently subjected to rolling. Further, the rolled product is repeatedly sintered in order to improve the compactness of the

sliding material layer 4 and the bonding strength between the steel plate and the sintered powder layer so that a sintered composite material is produced. During sintering, Bi having the low melting point is melted so that the hard particles coexist with the molten Bi-phase.

Fig. 1A shows schematically a microstructure of the thus produced sliding material layer 4, of the invention, which is a result of electron microscopic observation, in which the Bi-phase is dispersed in the copper alloy matrix and the hard particles coexist with the Bi-phase. Incidentally, there is shown a schematic drawing of microstructure of a sliding material layer of a comparative example in Fig. 1B which was prepared on the basis of an electron microscopic observation, the comparative example material being of a Cu-Sn alloy which comprises a graphite powder and a hard particles which is dispersed in the copper alloy matrix.

The thus prepared sintered composite materials were sheared to have a previously determined size, respectively, and bent to a cylindrical form. The cylindrically formed materials were machined to bearings 1 as shown in Fig. 4.

A wear and a seizure tests were carried out with regard to invention and comparative specimens of which chemical compositions are shown in Table 1. The wear test was conducted in accordance with the

requirements as shown in Table 2. The seizure test was conducted in accordance with the requirements as shown in Table 3.

Table 1

	No.	Components (mass%)				Components (vol%)			Average grain size of hard particle (μm)	Wear test		Seizure test
							Hard particle			Wear amount of bearing (μm)	Wear amount of mating shaft (μm)	Max surface pressure without seizure (MPa)
		Cu	Sn	Bi	Fc	*Gr	Ni-B	$TiSi_2$				
Invention specimen	1	Bal.	9	5	-	6	4	-	25	7	0.2	30
	2	Ditto	3	18	2	4	7	-	25	7	0.5	35
	3	Ditto	9	8	-	-	3	-	7	12	0.5	25
	4	Ditto	2	8	-	4	-	1.5	10	13	0	25
	5	Ditto	5.5	2	-	4	3	-	7	8	0.5	25
	6	Ditto	3	12	2	-	7	-	25	8	0.3	30
	7	Ditto	9	5	-	6	-	6	2	15	0.1	30
	8	Ditto	9	5	-	4	0.5	-	25	17	0.1	25
Comparative specimen	1	Ditto	10	Pb:10	-	-	-	-	-	103	0.1	20
	2	Ditto	9	-	-	12	3	-	25	30	1	25
	3	Ditto	9	8	-	-	-	-	-	110	0	20
	4	Ditto	10	-	-	-	7	-	25	36	1.5	15
	5	Ditto	9	5	-	6	12	-	25	21	3	25
	6	Ditto	9	5	-	6	4	-	55	42	5	15

*Note: "Gr" means graphite.

Table 2

Item	Requirements
Inner diameter of bearing	20 mm
Width of bearing	15 mm
Circumferential rotational speed	0.1 m/sec.
Lubricant	Kerosene
Material of shaft	JIS S55C
Exerting test load	26 MPa
Test time	20 Hours

Table 3

Item	Requirements
Inner diameter of bearing	20 mm
Width of bearing	15 mm
Circumferential rotational speed	1.0 m/sec.
Lubricant	SAE#10
Material of shaft	JIS S55C
Exerting test load	Load accumulation by each 5 Mpa increase at each 15 minutes
Evaluation method	It was regarded that the seizure occurred, when temperature of the back surface of the test bearing exceeded 200°C or operational current of the driving motor abnormally increased.

As will be apparent from Table 1, invention specimens 1 to 8 are excellent in comparison with comparative specimens 1 to 6 with regard to wear resistance property (WEAR AMOUNT OF BEARING) and anti-seizure property (MAX SURFACE PRESSURE WITHOUT SEIZURE), and the former specimens have smaller attack property (WEAR AMOUNT OF MATING SHAFT) against the mating shaft than the latter specimens.

Referring to Table 1, comparative specimen 1 comprises Pb instead of Bi and no hard particles.

Comparative specimen 3 comprises Bi and no hard particles. Both comparative specimens 1 and 3 without hard particles are inferior in wear resistance property and anti-seizure property, especially inferior in wear resistance property.

On the other hand, comparative specimen 4 comprises 7 vol% of hard particles but no Bi. Thus, it is inferior in wear resistance property and anti-seizure property in comparison with invention specimens 2 and 6 comprising Bi, and has higher attack property against the mating shaft (namely, it exhibits a larger size change of the mating shaft) due to lack of Bi-phase which has a cushioning action on hard particles.

Comparative specimen 2 comprises hard particles and no Bi like as comparative specimen 4. While comparative specimen 2 is substantially identical to the invention specimens with regard to anti-seizure property, regarding a reason of this, it is believed because graphite (Gr) contained in comparative specimen 2 exhibited a lubricating action.

Comparative specimen 5 comprises hard particles and Bi. While comparative specimen 5 is substantially identical to the invention specimens with regard to wear resistance property and anti-seizure property, since it comprises hard particles in an amount of 12 vol% which is more than 10 vol%, it

exhibits higher attack property against the mating shaft than invention specimens 1, 7 and 8 which comprises the same amounts of Sn and Bi as comparative specimen 5 assumedly because of enhanced attack property against the mating shaft due to much amount of hard particles.

Comparative specimen 6 comprises also hard particles and Bi. But, it exhibits a much wear amount of the bearing, inferior anti-seizure property, and especially a much wear amount of the mating shaft than invention specimen 1 comprising the same amount of hard particles as comparative specimen 6 because of a larger average grain size of 55 µm of hard particles which enhances the attack property against the mating shaft.

As will be understood from the above, according to the invention, the copper system sliding material is provided, according to which wear resistance and anti-seizure properties can be improved without use of Pb.

It should be noted that the invention is not limited to the above described embodiments with reference to the attached drawings and allows extensions or modifications as follows.

It is possible to use the invention material for main bearings supporting crank shafts or for con-rod bearings mounted in big ends of connecting rods, which are used as a pair of hemi-circular bearing halves.

The invention copper system sliding material is applicable to not only the bearing material for plain bearings which are used in motor vehicles, industrial machines, agricultural machines and so on but also it can be use as a general sliding material.

The invention copper system sliding material can be also produced by extrusion, forging or casting as well as by sintering.

Although the invention embodiments comprise no Pb, the invention copper system sliding material can comprise a small amount of Pb.

CLAIMS

1. A copper system sliding material which consists of a copper alloy comprising 0.5 to 15 mass% Sn, 1 to 20 mass% Bi and 0.1 to 10 vol% of hard particles, wherein Bi is present as a Bi-phase and the Bi-phase is dispersed in the copper alloy, and wherein the hard particles, having an average grain size of 1 to 45 μm, co-exist together with the Bi-phase.

2. A copper system sliding material according to claim 1, wherein the hard particles comprises one or more of boride, silicide, oxide, nitride, carbide and an intermetallic compound.

3. A copper system sliding material according to claim 1 or 2, wherein the copper alloy further comprises not more than 40 mass% of one or more elements of Fe, Al, Zn, Mn, Co, Ni, Si and P in an amount or a total amount.

4. A copper system sliding material according to any one of claims 1 to 3, wherein the copper alloy further comprises not more than 20 vol% of one or more of MoS_2, WS_2, BN and graphite in an amount or a total amount.

5. A copper system sliding material substantially as herein before described with reference to the accompanying drawings.

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Application No:	GB 0021664.8	**Examiner:**	Matthew Lawson
Claims searched:	1-5	**Date of search:**	31 January 2001

19

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S):

Int Cl (Ed.7): C22C

Other: Online: PAJ, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2312679 A	(TAIHO) - page 3 lines 5-12, page 4 line 37 - page 5 line 1 and page 8 line 38 - page 9 line 2.	1-4
X	EP 0681035 A2	(OLIN) - the whole specification, especially page 3 lines 37-40, page 4 lines 9-21 and page 5 lines 52-58.	1-3
X	WO 99/20806 A1	(TAIHO) - the whole specification.	1-4
X	JP 080283889 A	(NAKAGOSHI) - WPI Abstract Accession No. 97-017868/02 & PAJ Abv. 199702.	1-3
X	JP 080053725 A	(TAIHO) - PAJ Abv. 199606 and claims 1-5.	1-4
X	JP 070310133 A	(NAKAGOSHI) - WPI Abstract Accession No. 96-045582/05 & PAJ Abv. 199603.	1-3
X	JP 070150273 A	(TAIHO) - PAJ Abv. 199509 and claims 1-5.	1-4
X	JP 020194134 A	(TOSHIBA) - WPI Abstract Accession No. 90-272755/36 & PAJ Abv. 014470.	1-3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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Application No: GB 0021664.8 **Examiner:** Matthew Lawson
Claims searched: 1-5 **Date of search:** 31 January 2001

Category	Identity of document and relevant passage		Relevant to claims
X	US 5938864	(TOMIKAWA) - column 3 lines 18-21 & 26-29, column 7 lines 17-21 & 42-55 and Table 2 - material 3.	1-4

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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